Vertical Motion under Gravity
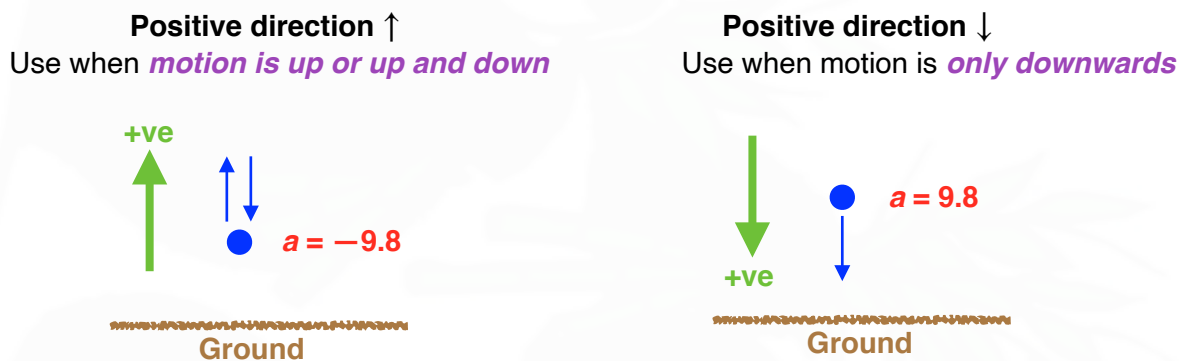
Starter

1. **(Review of last lesson)**
    A cyclist starts riding up a hill with velocity 8 m/s. At the top of the hill, which is 96 m long, the velocity is 4 m/s. Assuming constant acceleration, find its value.

2. **(Review of last lesson)** A stolen car, travelling at a constant speed of 40 m/s, passes a police car parked in a lay-by. The police car sets off three seconds later, accelerating uniformly at 8 m/s².
    (a)   How long does the police car take to intercept the stolen vehicle?
    (b)   How far from the lay-by, to the nearest metre, does the interception take place?

Notes

When an object is thrown vertically into the air, its acceleration is approximately 9.8 ms⁻²
downwards. Since the acceleration is constant, the $SUVAT$ *equations* can be used.

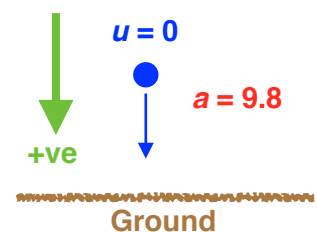When solving vertical motion problems, draw a quick sketch and choose which direction is positive — with up or down.

Positive direction ↑
Use when *motion is up or up and down*

Positive direction ↓
Use when motion is *only downwards*

+ve
$a = -9.8$
Ground

$a = 9.8$
+ve
Ground

N.B. *Acceleration* due to gravity *acts downwards* regardless of your chosen positive direction.

E.g. 1 (a)   A ball is thrown upwards into the air. If it takes 5 seconds to reach the top point, how long will it take to drop down to the point from which it was thrown.
     (b)   What can you say about the velocity at the highest point?

E.g. 2 A stone dropped from the top of a cliff takes 5 seconds to reach the beach.
     (a)   Find the height of the cliff.
     (b)   With what velocity would the stone have to be thrown vertically downward from the top of the cliff, to land on the beach after 4 seconds?

Working: (a)   The stone is dropped so $u = 0$
              Only downwards motion so the positive direction is downwards.
              $u = 0, a = 9.8, t = 5, s = ?$
              No $v \Rightarrow \quad s = ut + \dfrac{1}{2}at^2$

$$s = 0 + \frac{1}{2} \times 9.8 \times 5^2$$
$$s = 122.5$$

              The height of the cliff is 122.5 m

$u = 0$
$a = 9.8$
+ve
Ground

E.g. 3 A ball is thrown vertically upward and is caught at the same height 3 seconds later. Find:
      (a)   the distance it rose
      (b)   the speed with which it was thrown.

E.g. 4 A ball is thrown vertically with a speed of 7 m/s from a balcony 14 m above the ground.
      (a)   Find how long it takes to reach the ground if it is thrown
            (i)   downwards
            (ii)   upwards.
      (b)   Find also the speed with which it reaches the ground in each of these cases.

Video: Vertical motion under gravity

Vertical motion under gravity EQ

Solutions to Starter and E.g.s

Exercise
p469 20C Qu 1i, 2i, 3-8, 10

Summary
Vertical motion — since the acceleration is constant, the $SUVAT$ **equations** can be used.

When solving vertical motion problems, draw a quick sketch and choose which direction is positive — with up or down.

When motion is ***up*** or ***up and down***, have the ***positive direction upwards*** so $a = -9.8$.

When motion is ***down***, have the ***positive direction downwards*** so $a = 9.8$.

N.B. ***Acceleration*** due to gravity ***acts downwards*** regardless of your chosen positive direction.